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■

STATIONS ON SHIPBOARD IN THE MARITIME SERVICE

Auto Alarm Receiver Tolerances

ANNEX

We consider a system employing clocks and digital counters with a tolerance specified for the clock period. It is required to mark the duration of three intervals given the following constraints:

(a) The interval 0 - 1.5 seconds, where the indication of 1.5 seconds will come as close to the termination of a true 1.5 second duration as may reasonably be expected in the light of the specified clock tolerance, but in no event to come before the completion of the 1.5 second period;

(b) The interval 0 - 3.5 seconds, where the indication of 3.5 seconds will come as close to the termination of a true 3.5 second duration as may reasonably be expected in the light of the specified clock tolerance, but in no event to extend beyond the completion of the 3.5 second period;

(c) The interval 0 - 6 seconds with constraints similar to those in (a) above.

It is evident that in (a) we should set our clock timing, n , so that at the multiple, m , selected by the counter the interval will be greater than 1.5 seconds by at least an amount generated by the clock tolerance, Tmn. Let the difference mn - 1.5 = Tmn + p. Simultaneously, (b) requires that we should seek a second multiple, k , of the same clock rate, n , yielding an interval less than 3.5 by at least an amount due to the clock tolerance. Here let 3.5 - kn = Tkn + q. If we wish to relate q to p by the ratio of the multiple chosen for each (i.e. if q should be $\frac{k}{m}$ or roughly $\frac{3.5}{1.5}$

times greater than p), then we may proceed as follows:

$$mn - Tmn = 1.5 + p \quad (1)$$

$$kn + Tkn = 3.5 - \frac{k}{m}p \quad (2)$$

$$\text{or} \quad bmn + bTmn = 3.5 - bp \quad (3)$$

where $b = \frac{k}{m}$;

n = the period of the clock in seconds;

m = smallest number of counts yielding an interval $\geq$ 1.5 seconds;

k = greatest number of counts yielding an interval $\leq$ 3.5 seconds;

T = tolerance of the clock expressed as a decimal;

p = a kind of margin of safety in seconds defined by (1).

From (1) $$bmn - bTmn = 1.5b + bp \quad (4)$$

From (3) and (4) $$2bmn = 3.5 + 1.5b \quad (5)$$

$$\text{or} \quad mn = .75 + \frac{1.75}{b} \quad (6)$$

From (1) and (6) $$(1 - T)\left(.75 + \frac{1.75}{b}\right) = 1.5 + p \quad (7)$$

The optimum case obviously occurs when p = 0.

Under this limiting condition, we can solve for b, given any tolerance T.

Thus if we have a clock tolerance of .02, then the limiting value of b is 2.2418300653595. Since b is defined in terms of a rational fraction with integral numerator and denominator, its value may be approximated by the following series of ratios, all less than the limiting value.

Table I

Ratio	Decimal Values
6 : 3	2.0
11 : 5	2.2
20 : 9	2.222
29 : 13	2.23076923....
38 : 17	2.235294....
47 : 21	2.238095....
56 : 25	2.24
65 : 29	2.2413793103448
limit	2.2418300653595

Present day equipment is usually set up for a ratio of 7 : 3 with a clock timing of n = .5 seconds. This of course allows for a tolerance of zero as may be seen from equation (7).

$$(1 - 0)\left(.75 \div \frac{1.75}{\frac{7}{3}}\right) = \frac{3}{4} + \frac{\frac{7}{4}}{\frac{7}{3}} = \frac{3}{4} + \frac{3}{4}$$

$$= 1.5$$

Consequently for this value T = p = 0 and, therefore, this ratio 7 : 3 which equals 2.333.... is unacceptable. However, from the point of view of retrofitting, it is desirable to leave n as close as possible to .5 seconds, to have b represented by a simple fraction whose numerator and denominator are integers as close to 7 and 3 respectively as is practicable, and whose T is of the order of .02.

With T equal to .02, three ratios from the table commend themselves to our attention: 6 : 3, 11 : 5, and 65 : 29. The first offers a great advantage in that the retrofit presents no substantial economic problem. The clock timing is changed from .5 seconds to .5416 seconds, and the second count is reduced from 7 to 6. Unfortunately, p is high -- of the order of 6% -- so that the overall reject is in the neighborhood of 10%. That is to say, with a two percent clock tolerance, when the timing is set to .5416 in order to ensure the legitimacy of a space 1.5 seconds in duration, we can not guarantee the rejection of any space less than 1.6575. And similarly with the upper and lower dash limits.

If we reduce the clock timing to .3091 seconds and use the ratio b = 11 : 5, then the reject value drops to 1.576.. or approximately 5%. Here the possibility of false alarms is reduced but the price of retrofitting may be substantially increased.

Lastly, if we reduce the clock timing to .0528 and make use of the ratio b = 65 : 29, the reject value becomes 1.5614 or a little more than 4% (the theoretical minimum is .04= 2T). Here the rejection is close to ideal but the retrofitting may pose still greater difficulties.

The analysis thus far is based on a tolerance of T = .02 and the requirement $q = \frac{k}{m}p$. In this connection the simple ratio 9 : 4 looks attractive but its decimal value is equal to 2.25 and this is clearly greater than the 2.24183.... that is the limit for T = .02.

If however we solve equation (7) for T assuming values of $b = 2.25$ and $p_1 = 0$, we arrive at a value of tolerance equal to .01818. This value is only slightly more difficult to meet than .02, but it gives us the advantages of a high clock period of approximately .382, with low counts of 4 and 9 for the 1.5 and 3.5 intervals respectively. The reject for 1.5 is 1.555 or the minimum possible since $p = 0$ and the reject for 3.5 is 3.375 or the maximum possible since $q = 0$.

Another avenue worth exploring is to remove the restriction that $q = \frac{k}{m}p$. Here, for a tolerance of .02, a ratio of 12 : 6 : 3, and a choice of $n = .511$, we may arrive at reject values of 1.5637 for 1.5, and 3.0 for 3.5. Other combinations may easily be found. A summary of the cases considered is given in Table II.

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Table II

	$p = \frac{k}{m}q$				$p \neq \frac{k}{m}q$
Clock Tolerance T	.01818...	.02			
Ratio j : k : m	16 : 9 : 4	12 : 6 : 3	20 : 11 : 5	116 : 65 : 29	12 : 6 : 3
Clock Period n (seconds)	.3819444...	.5416	.30909...	.052785...	.511
mn	1.52777...	1.625	1.54545...	1.53076923...	1.533
Tmn	.02777...	.0325	.030909...	.03061538...	.03066
(1 - T) mn	1.5	1.5925	1.514545...	1.500153846	1.50234
(1 - T) mn - 1.5 =p	0	.0925	.014545...	.0001538	.00234
Reject 1.5 = (1 + T) mn	1.5555...	1.6575	1.576363...	1.56138461	1.56366
kn	3.4375	3.25	3.4	3.43103448	3.066
Tkn	.0625	.065	.068	.06862069...	.06132
(1 + T) kn	3.5	3.315	3.468	3.49965517...	3.12732
3.5 - (1 + T) kn =q	0	.185	.032	.00034483	.37268
Reject 3.5 = (1 - T) kn	3.375	3.185	3.332	3.36241379	3.00468